END CHAMFER STUDY AND FIELD MEASUREMENTS OF THE BEPCII DIPOLES *

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Abstract

The new BEPCII double ring will be added in the existing BEPC tunnel. There are more then 40 bending magnets named 67B in the new ring. The 67B is conventional 'C'-type dipole magnet. The magnetic field properties are improved by the magnet end effect. The end effect have been studied and minimized by a proper end chamfer. Magnetic measurements of the prototype and productions are carried out using the translating integral long coil. The developing process of pole end chamfers and the measurement results of the 67B prototype and batch production are described in the paper.

INTRODUCTION

There are 40 dipoles 67B with effective length 1.4135m in BEPCII new ring. The prototype of 67B was fabricated in IHEP in May 2004. Main parameters for the dipole 67B are given in table 1.

Table 1:BEPC II main dipole parameters

Nominal energy(GeV)	1.89
Energy Range(GeV)	1.0~2.1
Effective length (m)	1.4135
Gap height (mm) 67	
Central field *B* (Gs)	0.76578
Nominal current(A)	771.2
Bending angle (rad)	0.154685
GFR (H×V) (mm×mm)	108×43
Good field uniformity	
$\Delta BL/BL<1.3\times10^{-3}$	B2/B1:
	$<1.5\times10^{-4}$@1. 89
	$<5\times10^{-4}$@1~2. 1
	B3/B1:
	$<6\times10^{-4}$
	B5/b2:
	$<5\times10^{-4}$
	B7/B1:
	$<10\times10^{-4}$

The dipole is a C-type magnet. The required good field region extends horizontally from -67.65mm to +67.65mm. The translating integral long coil technique is used to characterize the integral field quality and the transfer function of the prototype and production magnets. Because of the magnet end effect influence, the integral field distribution of the three dimensions will not be the same as the two dimensional solution obtained using opera 2D. The removable pole ends are inserted in the prototype. Chamfering at both end sides of dipole magnet can compensate for the unwanted field harmonic components.

MEASUREMENT METHOD

The prototype was measured by the translating integral long coil at 771.5A and 857.2A(corresponding to 1.89GeV and 2.1GeV)respectively. The translating measurement coil machine is shown as follow (see figure1).

Fig.1. BEPC II dipole being measured

When the exciting current of the magnet is stable the long coil is moved across the mid-plane by the machine. The induced voltage from the long coil is fed to PDI 5025 Digital Integrator and then switched to counters. After processing of the counters by IPC the distribution of the integral field error can be obtained. The distribution of the integral field error of the prototype was measured by Hall probe. The two measurement methods produce equivalent results. The chamfer is made according to the long coil results. Multipole coefficients were extracted from the long coil results by fitting a polynomial to the data. The fitting order number of polynomial should be chosen carefully.

END CHAMFER

By taking advantage of end chamfer the systematic harmonic terms such as the sextupole component and the non-systematic harmonic terms can be reduced to satisfy the requirement. Otherwise, chamfering can avoid the field saturation at magnet edges

The chamfer was developed based on the long coil results at 771.5A corresponding to nominal 1.89GeV operation of the BEPC II . The blue line in figure 2 shows

0-7803-8859-3/05/$20.00

that the distribution of integral field error before chamfer inside the good field region(GFR) is 1.9×10^{-3}.The homogeneous requirement of the dipole should be 1.3×10^{-3}. The Table 3 shows the Multipole coefficients before the end chamfering. It is observed that some of the coefficients are higher than the requirement, particularly the sextupole component..

Table 2:The multipole coefficients before and after chamfer

	Before chamfer	chamfer
n	bn	bn
7	-3.929E-4	-1.917E-4
6	-8.811E-5	2.130E-5
5	5.331E-4	5.261E-5
4	-2.388E-5	-6.900E-5
3	-1.781E-3	1.530E-4
2	-1.743E-4	-5.185E-5

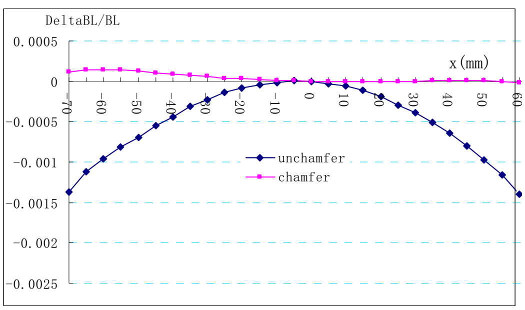

Fig.2. The distribution of integral field error

The First Chamfer

The aim of the first step of chamfer is to reduce the field nonlinearity. The chamfer depth is calculated according to the formula:

$$d(x) = \alpha \cdot \frac{L_{eff}}{2} \cdot [\frac{\Delta BL}{BL}(x) - \frac{\Delta BL}{BL}(ref)]$$

α: the relaxation coefficient

$\frac{\Delta BL}{BL}(x)$:integral field error at x ($-70\text{mm} \leqslant x \leqslant 70\text{mm}$)

$\frac{\Delta BL}{BL}(ref)$: integral field error at reference point.

Nominally, the chamfer angle is 45° . The optimum shape of end chamfer is showed in figure 3.

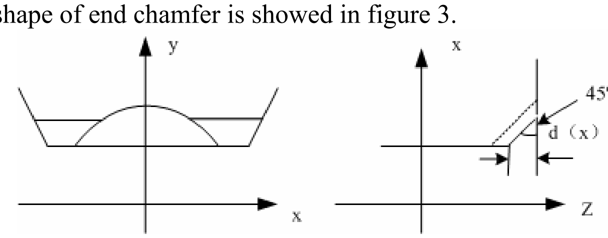

Fig. 3. The optimum shape of end chamfer

After the first chamfer the distribution of the integral field error inside the GFR is reduced to 5.5×10^{-4} from 1.9×10^{-3}.Though the uniformity of the integral field satisfies the requirement, the multipole coefficients are still higher than the requirement. The sextupole coefficient is -1.32×10^{-3} , the 10-pole coefficient is 1.31×10^{-3}

The Second Chamfer

The main goal of the second step of chamfer is to reduce the allowed components including 6-pole 10-pole and 14-pole. The sextupole component is still higher than the specification after the first chamfer. It indicates that the chamfer depth in the centre is not enough. According to the harmonic end shim analysis results, the zero shim positions for each multipoles are different which shown in table3. The width of effectual end shim should be larger than the multipole zero shim positions. In order to avoid the field saturation at magnet edge the removeable poles are cut by 6 mm with 45°.

Table 3: zero shim points

	Zero shim position (y0)	Angle (rad)
B3n	±0.577	±π/6
B4n	0, ±1	0, ±2π/8
B5n	±0.325, ±1.376	±π/10 ±3π/10
B6n	0,±0.577, ±1.732	0,±2π/12, ±4π/12
B7n	±0.228, ±0.797, ±2.076	±π/14 ±3π/14, ±5π/14

y0 means half height of gap.

After the second chamfer n=3,5 components are reduced to -1.7×10^{-4} and 5.7×10^{-4} respectively.

The Third Chamfer

Because the dipole is C-type configuration, the field distribution is not symmetrical. To make the different chamfer depth at open side and close side, The quadrupole component is reduced to less than-1.5×10^{-4} .

The third chamfer measurement results at 771.5A is showed in figure 2. The multipole components of the third chamfer are showed in table 3.Fifure 4 gives the last chamfer depth.

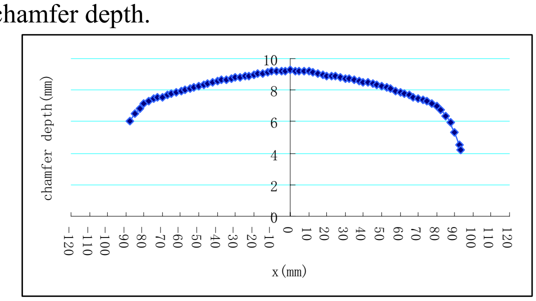

Fig.4. the last chamfer depth

SUMMARY

Nearly 30 magnets have been fabricated by now. The measurement results of production demonstrate that the chamfer shape is suitable.

ACKNOWLEDGMENTS

The authors would like to thank Prof. Hou for giving invaluable help and also appreciate colleagues in the Experimental Factory of IHEP.

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